Chapter 5 – Resource Plan Development & Analysis

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5 Resource Plan Development and Analysis

5.1 Overview of Scenario Planning

TVA chose to employ a scenario planning approach in the IRP. Scenario planning provides an understanding of how strategic decisions, both immediate and future, would perform under conditions that varied considerably from those considered most likely to occur. For example, we may plan for demand to grow at least 2% per year for the next 10 years, but what if it grows at 4% per year instead? What decisions have we taken that we might regret in that scenario? What decisions can we delay to provide the flexibility to respond? What if demand does not grow at all? Near-term decisions that are common across different scenarios may imply that these decisions are less “risky” since they perform well in most states of the world, whereas major differences in those decisions and the choices implied within those decisions could indicate a high potential for regret in the event of stresses. Scenarios provide a structured framework within which to consider and analyze various supply and demand options in a way that provides decision makers with valuable information about the robustness of those decisions.

Scenarios are different than analytical or quantitative models. Those models focus on what is statistically likely, based largely on historical and/or market data, and operate under the assumption that the future evolves approximately like the past. Scenarios do not represent one specific set of future conditions, nor do they assign probabilities or likelihoods to certain futures arising, but seek only to identify plausible futures that should be studied when developing a long-range resource plan.

In order to provide a planning framework within which specific strategies could be analyzed within the context of the IRP, scenarios were developed to:

- Bind key uncertainties to create a wide range of possible outcomes that would place sufficient stress on each planning strategy.
- Present a set of conditions that were "plausible" – not intended to predict the future but to frame how possible futures *could* unfold.

The design of the scenarios utilized in the 2010 IRP study followed a consistent five-step process shown in the figure below:

Figure 5-1 – TVA Scenario Development Process

- **Document Issue or Decision:** Document how the scenarios will align with the overall IRP development process.
- **Identify Uncertainties to be Evaluated:** Consider regulatory/legislative, economic/financial, social, technological, and other factors. Compare with uncertainties identified by other utilities in recent plans.
- **Identify the Key Uncertainties:** For each uncertainty, consider the range of variation and the relative impact to long-term plans.
- **Develop Scenarios Around Key Uncertainties:** Identify the scenarios that logically result from various combinations of the key uncertainties. For each scenario, create a narrative to be used for planning.
- **Assess Implications of Scenarios:** Ensure that scenarios will be useful in evaluating different business options and "stress" planning decisions.

5.2 Key Uncertainties that Define the Scenarios

Uncertainties are the key drivers that define the scenarios considered in the resource planning process. TVA developed a list of key drivers, or uncertainties, that were used as building blocks to develop scenarios for the IRP. These uncertainties are listed in the figure below:

Figure 5-2 – Key Uncertainties

Key Uncertainty	Description
Greenhouse gas (GHG) requirements	Reflects level of emission reductions (CO_2 and other GHG) mandated by federal legislation plus the cost of carbon allowances.
Environmental outlook	Changes in regulations addressing: • Air emissions (exclusive of GHG) • Land • Water • Waste
Energy Efficiency and Renewable Energy Standards (RES)	Reflects mandates for minimum generation from renewables and the viability of renewable generation sources. It includes the percentage of the RES standard that can be met with Energy Efficiency.
Total load	• Reflects variance of actual load to what is forecast • Accounts for benefits of DSM/EE penetration
Capital expansion viability & costs	For nuclear, fossil, other generation, and transmission, includes risks associated with: • Licensing • Permitting • Project schedule
Financing	• Financial cost (interest rate) of securing capital
Commodity prices	Includes natural gas, coal, oil, uranium, and spot price of electricity.
Contract purchase power cost	Reflects demand cost, availability of power and transmission constraints.
Change in load shape	Includes effects of factors such as: • Time-of-use rates • Plug-in Hybrid Electric Vehicles (transportation) • Distributed generation • Economics changing customer base • Energy storage • Energy efficiency • Smart grid / demand response
Construction cost escalation	Includes the following for nuclear, fossil, and other generation: • Commodity cost escalation • Labor and equipment cost escalation

The final set of scenarios selected for use in the IRP was then further refined to ensure the following characteristics:

- Each scenario is distinct and reflects a plausible, meaningful future world (e.g., uncertainties related to cost, regulation and environment) that TVA could find itself in over the horizon covered in the IRP. Each scenario placed sufficient stress on the resource selection to provide a foundation for analyzing the robustness, flexibility and adaptability of each combination of various supply and demand options (portfolios).
- Captured relevant key stakeholder interests, to the extent possible.

A summary of the six scenarios selected for this IRP study is given in the figure below:

Figure 5-3 – Scenarios Key Characteristics

Scenario	Key Characteristics
1 Economy Recovers Dramatically	• Economy recovers stronger than expected and creates high demand for electricity • Carbon legislation and renewable electricity standards are passed • Demand for commodity and construction resources increases • Electricity prices are moderated by increased gas supply
2 Environmental Focus is a National Priority	• Mitigation of climate change effects and development of a "green economy" is a priority • The cost of CO_2 allowances, gas and electricity increase significantly • Industry focus turns to nuclear, renewables, conservation and gas to meet demand
3 Prolonged Economic Malaise	• Prolonged, stagnant economy results in low to negative load growth and delayed expansion of new generation • Federal climate change legislation is delayed due to concerns of adding further pressure to the economy
4 Game-changing Technology	• Strong economy with high demand for electricity and commodities • High price levels and concerns about the environment incentivize conservation • Game-changing technology results in an abrupt decrease in load served after strong growth
5 Reduce Dependence on Foreign Energy Sources	• The U.S. focuses on reducing its dependence on non-North American fuel sources • Supply of natural gas is constrained and prices for gas and electricity rise • Energy efficiency and renewable energy move to the forefronts as an objective of achieving energy independence
6 Carbon Regulation Creates Economic Downturn	• Federal climate change legislation is passed and implemented quickly • High prices for gas and CO_2 allowances increase electricity prices significantly • U.S. based energy-intensive industry is non-competitive in global markets and leads to an economic downturn

In addition to these six scenarios, the IRP also includes a baseline scenario that closely resembled TVA's long-term planning outlook at the time the original scenarios were developed. For further reference, a detailed description of the seven scenarios used in the study is included at the end of this chapter in Figures 5-10 and 5-11.

In developing specific numerical values for each of the uncertainties that will define each of the scenarios, the following assumptions were used:

- Climate change uncertainty is based upon stringency of requirements, timeline required for compliance and cost of CO_2 allowances.
- An aggressive EPA regulatory schedule is expected to lead to additional compliance requirements (e.g., Hazardous Air Pollutants Maximum Achievable Control Technology (HAPs MACT), revised ambient air standards, etc.).
- Command and control regulation for HAPs MACT will likely drive plant-by-plant compliance.
- Renewable Energy Standards (RES) will help accomplish greenhouse gas reduction as required at the federal level.
- The spot price of electricity will be correlated with the price of natural gas and coal.
- Demand is primarily driven by economic conditions but is also affected by energy efficiency, demand response and other factors.
- Schedule risk is related to demand and uncertainty of permitting and licensing of generation and transmission projects.
- Economic conditions and associated inflationary pressures are the primary drivers for changes in financing costs.
- Construction costs are driven by demand and availability of labor, equipment, design and raw materials. Economic conditions are the primary driver, but the legislative/regulatory environment can apply additional pressure by introducing uncertainty related to potential schedule impacts.
- Cost and availability of contract power purchases are primarily driven by economic conditions and local area demand (i.e., load growth).

5.3 Planning Strategies

Planning strategies are designed to test the various business options and portfolio choices that TVA might consider to determine how each strategy performs when stressed by the scenarios developed. It should be noted that key attributes or elements of each strategy are within TVA's control, and thereby, relevant in making decisions. Also note that this is very different from the scenarios discussed in the previous section, which describe plausible futures, and encompasses factors that are not within of TVA's control. The link is between choice and outcome. The choices TVA makes in developing its portfolio of options for the future (strategy) will be subject to forces outside of TVA's control, and outcomes will be highly dependent on the robustness and the choices made in designing strategies. Poorly developed strategies will not perform well (bad outcomes) whereas robust and well-designed strategies will perform well over many possible futures (good outcomes).

The planning strategies considered in the IRP frame multiple distinct portfolios that are then tested across multiple scenarios. Each alternative portfolio is described by a unique combination of strategic objectives and/or constraints. The objective in the IRP is to identify one or more strategies that provide stability and flexibility over an uncertain long-term future, as well as robust performance across multiple possible worlds. This last objective is closely related to the no-regrets planning framework, and refers to the fact that a good strategy is one that performs relatively well even when the future unfolds in a way that was not foreseen in the baseline forecast.

In developing the planning strategies, TVA identified nine distinct categories of attributes to describe them. The choice of attributes was influenced by comments received during the public scoping and focused on those assumptions that would have the greatest impact on the options that might be included in the long-term resource plan. These attributes fall into one of two groups:

1. **Defined Model Inputs**: Attributes that are scheduled or pre-determined. These can refer to the timing of technology of specific asset decisions like the online date of a new natural gas plant. The capacity optimization model selects a resource portfolio that presumes these resources already exist and plans around these options.

2. **Constraints in the Model Optimization**: Attributes that constrain the optimization of asset choices include minimum build times, technology limitations, and other strategic constraints including limits on market purchases. The capacity optimization model will identify a solution (resource portfolio) that is consistent with these constraints.

The attributes for the planning strategies are described in the following figure:

Figure 5-4 – Attributes of Planning Strategies

Attribute	Description	Type
EEDR Portfolio	The level of energy efficiency (EE) and demand response (DR) included in each strategy.	Defined Model Input
Renewable Additions	The amount of renewable resources added in each strategy.	Defined Model Input
Fossil Asset Layups	A proposed schedule of coal unit layups that will be tested in each strategy.	Defined Model Input
Energy Storage	Option to include a pumped-storage hydro unit in selected strategies.	Defined Model Input
Nuclear	Constraints related to the addition of new nuclear capacity.	Constraint
Coal	Limitations on technology and timing for new coal-fired plants.	Constraint
Gas-Fired Supply (Self Build)	Limitations on gas-fired unit expansion.	Constraint
Market Purchases	Level of market reliance allowed in each strategy.	Constraint
Transmission	Type and level of transmission infrastructure required to support resource options in each strategy.	Constraint

TVA combined these nine attributes to create five distinct planning strategies for examination in the IRP study. Those strategies are:

Figure 5-5 – Planning Strategies Key Characteristics

Planning Strategy	Key Characteristics
A Limited Change in Current Resource Portfolio	• Retain and maintain existing generating fleet (no additions beyond Watts Bar 2) • Rely on the market to meet future resource needs
B Baseline Plan Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Assumes idling of 2000 MW of coal capacity • Includes EEDR portfolios and wind PPA's
C Diversity Focused Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Increases the contribution from EEDR portfolio and new renewables • Adds a pumped-storage hydro unit • Assumes idling of 3000 MW of coal capacity
D Nuclear Focused Resource Portfolio	• Allows for nuclear expansion after 2018 and new gas-fired capacity as needed • Includes an increased EEDR portfolio compared to other strategies • Assumes idling of 7000 MW of coal capacity • Includes new renewables (same as planning Strategy C) • Includes a pumped-storage hydro unit
E EEDR and Renewables Focused Resource Portfolio	• Assumes greatest reliance on EEDR portfolio of any strategy and includes largest new renewable portfolio • Assumes idling of 5000 MW of coal capacity • Delays nuclear expansion until 2022

A more detailed description of the planning strategies is shown at the end of this chapter in Figure 5-12 with defined model inputs shown with highlighted background.

5.4 Portfolio Development

In order to guide planning decisions, TVA develops sets or portfolios of assets made up of various generating technologies and cost characteristics. To do so, TVA employs a complex mathematical technique known as optimization, where an “objective function” (in this case, total cost) is minimized subject to a number of constraints (with the most important being balancing supply and demand). The technical term for the optimization technique applied is *mixed integer linear programming*. Each planning strategy is “optimized” for each of the seven scenarios, with the end result being a set of 35 distinct portfolios made up of optimized variants of each planning strategy in all seven worlds. Given the nature of the analysis, certain elements of the strategy are the same across worlds (i.e. emphasis on EEDR, reliance on nuclear energy), while others (amount of natural gas-fired capacity, market purchases) are a function of the interplay between each planning strategy and the world within which it is analyzed.

As described above, TVA employs a form of mathematical analysis known as optimization to design portfolios within each world. TVA utilizes an industry standard software model developed by Ventyx known as System Optimizer. System Optimizer works by adding or subtracting assets into a portfolio based on minimizing the Present Value of Revenue Requirements (PVRR) subject to the following constraints:

- Energy Balance
- Reserve Margin
- Generation and Transmission Operating Limits
- Fuel Purchase and Utilization Limits
- Environmental Stewardship

The model generates multiple combinations of resources for each year of the study period and computes the costs of each combination. Capital costs for supply-side options are amortized for investment recovery using a real economic carrying cost method that accounts for the unequal economic lives of generating assets and ensure that assets with higher capital costs, but longer service lives, are not unduly penalized relative to assets with lower capital costs but relatively shorter economic lives.

Capacity optimization tools like System Optimizer use a simplified dispatch algorithm to compute production costs because of the number of possible states evaluated. The model uses a “representative hours” approach, in which average generation and load values in each representative period in a week are scaled up appropriately to span all hours of the week and days of the months.

Year-to-year changes in resource mix are then evaluated and infeasible "states" are eliminated. The least cost (i.e., lowest PVRR) path through the possible states in the study period is retained as the optimized capacity plan.

Each of the 35 portfolios is also evaluated using an hourly production costing algorithm that calculates detailed production costs of each portfolio after accounting for fuel and other variable operating costs. These detailed cost simulations provide total strategy costs and financial metrics that are then used to rank and select the preferred planning strategy. This analysis is accomplished using another Ventyx product called Strategic Planning (MIDAS). This software tool uses a chronological production costing algorithm and includes financial planning data that can be used to assess plan cost, system rate impacts, and financial risk by utilizing a variant of Monte Carlo analysis; a sophisticated analytical technique that varies important drivers and creates a distribution of total costs, rather than a single point estimate, to allow for risk analysis. The Monte Carlo (also known as stochastic) analysis in MIDAS uses 13 key variables and allows for random walking of values in the Monte Carlo algorithm.

The variables selected by TVA for this analysis include:

- Commodity Prices – natural gas, coal, CO_2 allowances, SO_2 and NO_x allowances
- Financial Parameters – interest rates and electricity prices
- Operating Costs – capital and O&M
- Dispatch Costs – hydro generation, fossil and nuclear availability
- Load Forecast Uncertainty

The Monte Carlo analysis employs 72 iterations to describe the uncertainty associated with each of the portfolios created by the capacity optimization model. The expected value for the PVRR and short-term rates from these stochastic iterations represent the costs associated with each portfolio.

5.5 The Planning Strategy Scorecard

The identification of a preferred planning strategy involves a trade-off analysis that focuses on multiple metrics of cost, risk, environmental impacts and other aspects of TVA's overall mission. A strategy scorecard is used to facilitate this trade-off analysis. A scorecard template is shown in Figure 5-6 and is comprised of two sections: (1.) ranking metrics and (2.) strategic metrics:

Figure 5-6 – Planning Strategy Scorecard

	RANKING METRICS			STRATEGIC METRICS				
	Energy Supply			Environmental Stewardship			Economic Development	
Portfolios	Cost	Risk	Ranking Metric Score	Carbon Footprint	Water Impact	Waste Impact	Total Employment	Growth in Personal Income
		Total Score:						

In addition to the scorecard, a technology innovation narrative is also included, which is discussed in section 5.5.3.

5.5.1 Ranking Metrics

Ranking metrics are financial measures of cost and risk that are used to apply quantitative rankings to the planning strategies. The IRP study uses cost and risk metrics to identify the preferred planning strategy.

5.5.1.1 Plan Cost Metrics

The plan cost metric is a combination of both a PVRR metric and a short-term rate metric. The PVRR metric is the cumulative present value of total revenue requirements over the study period based on an 8% discount rate.

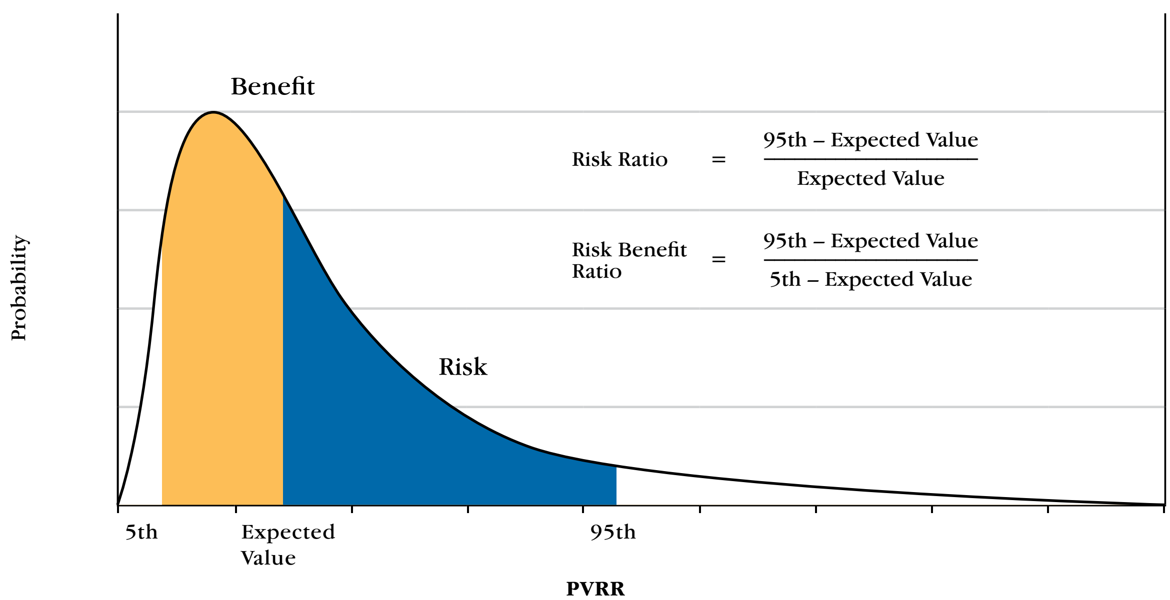
The short-term rate metric provides an alternative representation of the revenue requirements for the period 2011-2018 expressed per MWh. This metric was developed to focus on the near-term impacts to system cost in recognition of TVA's current debt cap of $30 billion and the likelihood that a majority of capital expenditures in the short term (prior to 2018) may have to be funded solely from rates.

By considering both PVRR and short-term rates, TVA is better able to evaluate the cost implications for various portfolios. Including both short-term and total revenue requirements facilitates a trade-off analysis of alternative resource plans, and allows TVA to more explicitly evaluate funding implications, consistent with stakeholder concerns about increasing rate pressures (see discussion in Section 2.2.5). The expected values for PVRR and short-term rates generated by the stochastic analysis are used to compare portfolios.

5.5.1.2 Financial Risk Metrics

PVRR risk metrics are also computed for each of the portfolios. Two indicators are used: a risk ratio and a risk/benefit ratio. Figure 5-7 provides a graphical explanation of how these risk ratios are computed:

Figure 5-7 – Financial Risk Metrics



The risk score for each portfolio is a combination of risk ratio and risk/benefit ratio. The risk ratio is represented by the potential of exceeding the expected PVRR and is similar to the Value at Risk technique used to capture risks in the financial sector. The risk/benefit ratio measures the potential of exceeding the expected PVRR but compares it to the benefit of not exceeding the expected PVRR expressed as a ratio. In other words, it compares the potential risks of a strategy with the potential benefits of that strategy to determine whether or not the "risks and rewards" balance is tipped in favor of the customer.

Each of these ranking metrics is based on a weighted formula:

Cost Metric = 0.65 * PVRR + 0.35 * short-term rates

Risk Metric = 0.65 * risk ratio + 0.35 * risk/benefit ratio

Ranking Metrics Score = 0.65 * cost + 0.35 * risk

5.5.2 Strategic Metrics

Strategic Metrics are paired with ranking metrics to complete the IRP scorecard for selection of preferred strategies.

5.5.2.1 Environmental Stewardship Strategic Metric

The environmental strategic metric was developed to evaluate air, water and waste impacts. In evaluating the air metric CO_2, sulfur dioxide, nitrogen oxide emissions, and mercury were calculated for each case. Emission trends for the later three emissions were steeply reduced as all cases assumed large plant layups (2000-7000 MW) or highly controlled (90% or better emission removal rates) operating units in the future. In all cases, these emissions all tracked similar trend lines for CO_2. Thus the air metric is represented as a CO_2 impact "footprint" factor (annual average tons).

Air Impact = Annual average tons of CO_2 emitted

All emission trends follow the same declining pattern, and no additional information was provided using all air emissions as opposed to CO_2 only. Costs associated with CO_2 emissions are included in all scenarios and are reflected in the PVRR for all the portfolios (see Figure 5-10).

The water component of the environmental strategic metric uses the thermal load produced through the condenser cooling cycle from steam generating plants as a measure of thermal impacts to the environment. The water impact is estimated based on the total heat dissipated by the condenser, expressed in BTUs, in the generation cooling cycle. The formula for the water impact is:

Water Impact = Generation by fuel type (GWH) x heat input x design factor

Design factors for the various generation sources expected to impact water (primarily fossil and nuclear) were based on actual data from the TVA fleet (averaged) or the design manufacturer's performance information for expected heat losses to the condenser.

In addition to air and water impacts, certain generation sources produce waste streams that require disposal. The waste component used in this analysis only focused on waste streams from coal and nuclear generation. The volumetric and disposal costs are used to better normalize for differences in mass generated (tons). Waste streams estimated include coal ash (fly and bottom ash), FGD/scrubber waste, and high- and low-level nuclear waste. The formula for the waste impact is:

Waste Impact = Fuel consumed (mmBTU) x waste factor x handling costs ($/ton)

Waste factors for coal ash were based on 2009 weighted coal laboratory analysis for the average heat content (BTU/lb) across the six coal basins that TVA purchases from and a weighted average ash percentage (also based on the 2009 coal basins analysis data). Separate weighted averages were calculated for each strategy to better reflect the fossil layup assumptions (0-7000 MW). The other sources of waste from coal plants are flue gas desulfurization controls, also known as scrubbers. Scrubbers aid in the removal of sulfur dioxide emissions, but produce calcium sulfate, or gypsum, as a by-product. The waste factor applied to scrubbers is based on historical average performance for the TVA scrubbed fleet, assuming current percentages (approximately 50%) of the TVA fleet is scrubbed in 2010. For future year calculations, it was assumed that all remaining TVA coal generation (based on fossil layup assumptions) are scrubbed.

Results for all coal waste streams were converted to tons and then multiplied by handling costs ($/ton) to compare to nuclear waste. It should be noted that the assumptions for coal waste generation are considered conservative since future scrubbers (dry) would be combined with other control technologies to capture the fly ash portion of coal ash in their waste stream, although they are represented in this calculation separately. Calculations also do not represent utilization of coal waste products for beneficial uses.

Like coal waste, nuclear waste streams are based on averages across TVA's existing six units and converted to tons and then multiplied by handling costs ($/ton) for comparison.

5.5.2.2 – Economic Development Metric

Economic metrics are included to provide an indication of the impact of each strategy on the general economic conditions in the TVA service area, represented by total employment and personal income indicators, as compared to the impacts that would be realized under Strategy B (Baseline Plan Resource Portfolio) in Scenario 7.

The IRP study defined economic impact as growth in regional economic activity. Measurement criteria include total personal income in “constant” dollars (i.e., with inflation accounted for) and total employment. These provide measures for the effects of the various planning strategies on the overall, long-term health or welfare of the economy for the next 20 years. This analysis concentrates on changes to the welfare of the overall economy due to the strategies. It does not address changes to the distribution of income or employment.

Two types of factors associated with the portfolios produced by a particular strategy in a given scenario affect the regional economic impact metrics:

1. Direct expenditures for labor and materials incurred in the Tennessee Valley during the construction and operation phases of an energy resource option.
2. Changes to the electricity bills of end-use customers of TVA electricity as a result of increased or decreased costs from the implementation of a particular portfolio (changes could be caused either by TVA rates or energy efficiency).

In general, the greater the direct regional expenditures associated with a particular portfolio, the more positive are the effects on regional economic development. This can be offset, however, by the fact that higher rates caused by higher costs have a negative effect on regional economic development. Thus, a resource portfolio that has high expenditures in the Tennessee Valley compared to other portfolios may also have high costs and high rates. The overall effect on the economic impact metrics for a particular planning strategy may be positive or negative depending on the net sum of the expenditure effects and the cost effects. More details about the methodology used to determine the economic impact metrics for the planning strategies can be found in Appendix B.

5.5.3 Technology Innovations Narrative

In addition to the ranking metrics and strategic metrics, a brief narrative that discusses the technology innovations associated with each planning strategy will be prepared (see Chapter 7) to provide the TVA Board with an insight into the technology utilization implicit in each strategy. This narrative is not a metric, but will be included along with the fully populated scorecard as background information that could be considered when selecting a preferred planning strategy. The technology innovation narrative will discuss what technologies would require investment to enable the resource mix identified in each strategy (e.g., a planning strategy with extensive EEDR may need smart grid investments for energy savings to be fully realized).

5.6 Scorecard Calculation and Color Coding

The ranking metrics in the scorecard are expressed in terms of a 100-point score by translating the metric values while ensuring that the relative relationship between the actual values for each portfolio in the strategy is maintained. The process of computing the scores is:

- Actual values of ranking metrics (e.g., PVRR, short-term rate impacts) will be converted to a unit less score on a 100-point scale. Using this type of scoring helps to assess and prioritize risk to find the best possible solution.
- The highest ranking (“best”) value will receive 100.
- The rest of the scores will be based on their relative position to the “best” value (i.e., a value that is 75% of the “best” would receive a 75).
- A color-coding method is used to assist in visual comparison of portfolio results. The coding is done within a given scenario. The “best” value for each metric is coded green; the “worst” value is coded red; and the values in between are shown with a shaded color that corresponds to the relationship of the score values.

An example of how this translation from actual values to ranking metric score is shown in Figure 5-8 (this example shows the conversion for the short-term rate metric):

Figure 5-8 – Ranking Metrics Example

Raw ranking metric value for short term rate impacts in scenario 1 are shown to right.

Ranking Metric Scores

	Strategy	Scenario 1
Average of ST Rates $/MWh (level 2011-18)	A	76.82
	B	78.67
	C	79.95
	D	84.61
	E	80.41

The "best" (in this case lowest) value within a scenario gets a score of 100

Strategy D is 10.13% higher than the "best" value and receives a score of 89.97

Scores are converted from the raw scores as shown and are included in the planning strategy score cards

Converted Ranking Metric Scores

	Strategy	Scenario 1
Average of ST Rates $/MWh (level 2011-18)	A	100.00
	B	97.59
	C	95.93
	D	89.97
	E	95.34

All other scores are assigned a value based on their relative position to the "best" score

The strategic metrics are included in the scorecard in two ways: for environmental stewardship metrics, metric values are translated into a relative scoring system known as a Harvey Ball rating system, and the economic impact metrics are represented by a percent change from a reference case. For the environmental metrics, in a given scenario the data are coded so that the relative relationship (rank order) among the strategies is indicated by the amount of the ball that is filled in. An example of how this translation is done is shown in Figure 5-9 on the following page.

Figure 5-9 – Example Scoring Process – Carbon Footprint

- The following is an example of how the "Harvey Ball" ratings will be applied to the Carbon Footprint strategic metric
- Expected values for annual CO_2 emissions from stochastic analysis are shown to the right

Average Annual CO_2 Emissions (Million Tons)

	Scenarios						
Strategy	1	2	3	4	5	6	7
A	2,054	1,719	1,402	1,775	1,723	1,190	1,767
B	1,774	1,461	1,317	1,518	1,480	1,138	1,533
C	1,673	1,418	1,210	1,408	1,422	1,035	1,427
D	1,468	1,170	1,058	1,256	1,204	962	1,249
E	1,613	1,299	1,106	1,410	1,303	959	1,352

- Planning strategies are ranked based on their performance within each scenario

  In this example, 1=highest and 5=lowest
- In this example, quantitative data is available to support the ranking, however, other strategic metrics may require qualitative assessment for ranking

Carbon Footprint Rankings Within Scenarios

	Scenarios						
Strategy	1	2	3	4	5	6	7
A	5	5	5	5	5	5	5
B	4	4	4	4	4	4	4
C	3	3	3	2	3	3	3
D	1	1	1	1	1	2	1
E	2	2	2	3	2	1	2

- The appropriate "Harvey Ball' is assigned based on the rankings

Populated Carbon Footprint Strategic Metric

Legend	
●	Better
◕	↑
◑	
◔	
○	

	Scenarios						
Strategy	1	2	3	4	5	6	7
A	○	○	○	○	○	○	○
B	◔	◔	◔	◔	◔	◔	◔
C	◑	◑	◑	◕	◑	◑	◑
D	●	●	●	●	●	◕	●
E	◕	◕	◕	◑	◕	●	◕

For the economic impact metrics, data are included in the scorecard as a percent change from the reference case (Strategy B in Scenario 7). For this draft report, only the range of possible impacts has been evaluated (instead of computing impacts for all 35 portfolios) by computing the values for each planning strategy in Scenario 1 and Scenario 6. The changes in employment and personal income in these scenarios relative to the reference case (Strategy B in Scenario 7) is indicative of the maximum impacts that would result in any of the other scenario/strategy combinations.

5.7 Planning Strategy Evaluation

The scorecard is used to compare planning strategies by computing a score for each of the 35 portfolios evaluated in the study (seven portfolios to describe each of the five planning strategies). Scores are based on the expected value for the cost and risk metrics developed using a stratified Monte Carlo analysis as described in detail above. The ranking metrics are then weighted to compute the total score for each portfolio using the formulas described in the prior section.

Identification of the preferred planning strategy/strategies is accomplished using a three-step process that identifies a strategy or strategies for further evaluation based on the ranking metrics. The identification process is as follows:

Step 1 – Planning strategies are ranked by summing scores (the ranking metrics) for each portfolio that is produced in a given strategy over all scenarios (seven total) – this results in a Total Planning Strategy Score.

- Sensitivity analysis is conducted to refine preliminary results and/or capture other portfolio options. A preferred set of planning strategy alternatives are identified based on the ranking metrics.
- Resource portfolios are then identified from planning strategy alternatives that will serve to define the planning strategies for the purpose of comparative analysis and impact assessment.

Step 2 – Resource portfolios from the planning strategies selected in the prior step are used to define the breadth of options considered in the draft IRP and associated EIS.

- A sufficient number of portfolios will be presented to achieve a broad range of possible strategic options for TVA that maintains resource flexibility and responds to changing future conditions.
- Strategic metrics are combined with the ranking metrics for each of the selected reference resource portfolios to complete the scorecard.
- The initial scorecard is shared publicly during the comment period for the EIS and used to facilitate the discussion of trade-offs. This trade-off assessment is focused on consideration of the scorecard values – cost, risk, and the strategic metrics.

Step 3 – Following completion of a public comment period on the initial results, the identified reference resource portfolios are updated and re-scored. This may include consideration of additional sensitivity cases or alternative scenarios not included in the draft phase.

- The purpose of this additional analysis is to ensure that the basis for the recommendation of one or more planning strategies is not substantially changed due to new or updated information or planning assumptions.
- A short list of reference resource portfolios that enable TVA to implement one or more planning strategies are presented to the Board for consideration.
- The TVA Board sets strategic direction by the strategy or combination of strategies it decides to select.
- An implementing resource plan is identified that best enables TVA to pursue the planning strategy adopted by the Board. This implementing resource plan is subject to refinement based on changing circumstances, or annually as part of the capacity planning cycle.

Chapter 7 includes the results of the capacity planning and production cost modeling and their scores. It also identifies a recommended set of planning strategies for consideration during the public comment period. This study report will be updated following completion of step 3 in the evaluation process.

Figure 5-10 – Scenario Descriptions I

Uncertainty	Scenario 1 Economy Recovers Dramatically	Scenario 2 Environmental Focus is a National Priority	Scenario 3 Prolonged Economic Malaise	Scenario 4 Game-changing Technology	Scenario 5 Energy Independence	Scenario 6 Carbon Legislation Creates Economic Downturn	IRP Base Case
Greenhouse gas requirements	CO_2 price \$27/ ton (\$30/metric ton) in 2014 and \$82 (\$90/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price \$17/ ton (\$19/metric ton) in 2012 and \$94 (\$104/metric ton) by 2030. 77% allowance allocation, 28% by 2030	No federal requirement (CO_2 price = \$0/ton)	CO_2 price \$18/ ton (\$20/metric ton) in 2013 and \$45 (\$50/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price \$18/ ton (\$20/metric ton) in 2013 and \$45 (\$50/metric ton) by 2030. 77% allowance allocation, 41% by 2030	CO_2 price \$17/ ton (\$19/metric ton) in 2012 and \$94 (\$104/metric ton) by 2030. 77% allowance allocation, 28% by 2030	CO_2 price \$15/ ton (\$17/metric ton) in 2013 and \$56 (\$62/metric ton) by 2030. 77% allowance allocation, 39% by 2030
Environmental outlook	Same as Base Case	SO_2 controls 2017 NO_X controls Dec 2016 Hg MACT 2014 HAP MACT 2015	No additional requirements (CAIR requirements, with no MACT requirements)	Same as Base Case	Same as Base Case	Same as Base Case	SCR all units by 2017 FGD all units by 2018 HAPs MACT by 2015
Energy Effiiency (EE) & Renewable Electricity Standards (RES)	RES – 3% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	RES – 5% by 2012, 30% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	No federal requirement	RES – 5% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 40% or requirement	RES – 5% by 2012, 20% by 2021 (adjusted total retail sales) EE can meet up to 40% or requirement	RES – 5% by 2012, 30% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement	RES – 3% by 2012, 15% by 2021 (adjusted total retail sales) EE can meet up to 25% or requirement
Total load	Med grow to High by 2015; High Dist; Alcoa Returns in 2010+; USEC stays forever; Dpet Dist same as Base	Medium case, then 2012 40% rate increase; Low Dist; DS customer reductions (steel/ paper plants); USEC stays forever; Dept Dist same as Base	Low load case; Low Dist; Alcoa not returning, No HSC & Wacker; USEC leaves June 2013; Dept Disc same as Base	Med-High load growth through 2020, then 20% decrease 2021-2022 including USEC departure, reduced dist sales & extended TOU	Medium case, then 20% rate increase in 2014; unrestricted PHEV included; TOU	Medium load case 2010-2011; 2012 low case then flat w/no growth; USEC leaves 2013; Alcoa not returning, HSC & Wacker not in; TOU	Moderate growth
Capital expansion viability & costs	Moderate schedule risk	High schedule risk	Low schedule risk	Moderate schedule risk	Moderate schedule risk	Low schedule risk	Moderate schedule risk

Figure 5-11 – Scenario Descriptions II

Uncertainty	Scenario 1 Economy Recovers Dramatically	Scenario 2 Environmental Focus is a National Priority	Scenario 3 Prolonged Economic Malaise	Scenario 4 Game-changing Technology	Scenario 5 Energy Independence	Scenario 6 Carbon Legislation Creates Economic Downturn	IRP Base Case
Financing	Higher than base case—higher inflation due to higher economic growth	Higher than base case—higher inflation due to looser monetary policy supporting economic growth	Lower than base case—lower inflation due to lower economic growth	Same as base case—increased productivity due to technology leads to stronger economic wealth and non-inflationary money growth	Higher than base case—higher inflation due to looser monetary policy supporting economic growth	Lower than base case—lower inflation due to lower economic growth	Based on current borrowing rate
Commodity prices	Gas & coal higher than base case	Gas higher; coal lower than base case	Gas much lower & coal much higher than base case	Gas lower & coal slightly higher than base case	Gas & coal higher than base case	Gas & coal much lower than base case	Gas - $6-8/ mmBTU Coal - $40/ton
Contract Purchase Power Cost	Much higher cost & lower availability	Higher cost & lower availability	Same as base, then much lower cost with high availability	Higher cost & lower availability, then much lower cost with high availability after load decrease	Higher cost & lower availability	Lower cost with high availability	Moderate cost & availability
Construction Cost Escalation	Much higher than base case—high economic growth causes high demand for new plants and high escalation rate	Somewhat higher than base case—due to "construction costs escalating at high rate due to large volume of nuclear, renewables and env controls projects". High regulatory scrutiny adds to project costs	Lower than base case—low load growth leads to low escalation	This scenario has two stages of escalation: 1) higher than base due to high load growth early, then 2) lower escalation when game-changing technology hits	Somewhat higher than base case—moderately strong economy and load growth leads to somewhat higher than base escalation	Lower than base case—negative load growth, very weak economy and high renewables lead to low escalation	Moderate escalation

Figure 5-12 – Strategy Descriptions

Attributes	Scenario A Limited Change in Current Resource Portfolio	Scenario B Baseline Plan Resource Portfolio	Scenario C Diversity Focused Resource Portfolio	Scenario D Nuclear Focused Resource Portfolio	Scenario E EEDR and Renewable Focused Resource Portfolio
EEDR	1,940 MW & 4.725 annual GWh reductions by 2020 (Iteration 12)	2,100 MW & 5,900 annual GWh reductions by 2020 (FY11 LRFP / 10.75)	3,600 MW & 11,400 annual GWh reductions by 2020 (BLN case / 10.5)	4,000 MW & 8,900 annual GWh reductions by 2020 (based on EPRI)	5,900 MW & 14,400 annual GWh reductions by 2020 (aggresive / 11.1)
Renewable Additions	1,300 MW & 4,600 GWh competitive renewable resources or PPAs by 2020	Same as Planning Strategy A	2,500 MW & 8,600 GWh competitive renewable resources or PPAs by 2020	Same as Planning Strategy C	3,500 MW & 12,000 GWh competitive renewable resources or PPAs by 2020
Fossil Asset Layup	No fossil fleet reductions	2,000 MW total fleet reductions by 2017	3,000 MW total fleet reductions by 2017	7,000 MW total fleet reductions by 2017	5,000 MW total fleet reductions by 2017
Energy Storage	No new additions	Same as Planning Strategy A	Add on pumped-storage unit	Same as Planning Strategy C	Same as Planning Strategy A
Nuclear	No new additions after WBN2	First unit online no earlier than 2018 Units at least 4 years apart	Same as Planning Strategy B	First unit online no earlier than 2018 Units at least 2 years apart	First unit online no earlier than 2022 Units at least 2 years apart Additions limited to 3 units
Coal	No new additions	New coal units are outfitted with CCS First unit online no earlier than 2025	Same as Planning Strategy B	Same as Planning Strategy B	No new additions
Gas-Fired Supply (Self-Build)	No new additions	Meet remaining supply needs with gas-fired units	Same as Planning Strategy B	Same as Planning Strategy B	Same as Planning Strategy B
Market Purchases	No limit on market purchases beyond current contracts and extensions	Purchases beyond current contracts and contract extensions limited to 900 MW	Same as Planning Strategy B	Same as Planning Strategy B	Same as Planning Strategy B
Transmission	Potentially higher level of transmission investment to support market purchases Transmission expansion (if needed) may have impact on resource timing and availability	Complete upgrades to support new supply resources	Increase transmission investment to support new supply resources and ensure system reliability Pursue inter-regional projects to transmit renewable energy	Same as Planning Strategy C	Potentially higher level of transmission investment to support renewable purchases Transmission expansion (if needed) may have impact on resource timing and availability

Defined model inputs (yellow) ☐ Optimized model inputs